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Fisheries Discards – Waste of a Resource or a Necessary Evil?

(Photo: Bryce Beukers-Stewart)

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Fisheries Discards – Waste of a Resource or a Necessary Evil?

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ABSTRACT:

Fisheries discards are often seen as an enormous waste of resources and an impediment to the rebuilding of fish stocks. However, many traditional fisheries management measures have effectively encouraged discarding in an effort to enforce catch quotas and protect undersize fish or undesirable species. Discarding is currently a particularly contentious issue in European fisheries, prompting the European Commission to review its approach to managing discards. Of key concern is the North Sea which accounts for some of the highest discard rates in the world. It is jointly managed under two different policies (The European Common Fisheries Policy and the Norwegian Marine Resources Act). In Norwegian waters discarding is banned, whereas in EU waters discarding is widespread. To assess the ecological and economic effectiveness of the Norwegian ban on discards we examined its effect on Northeast Arctic fish stocks. These are considered to be biologically isolated from those in the North Sea, allowing for a meaningful comparison. By analysing normalised spawning stock biomass over a 20 year period we provide evidence that the Norwegian approach in the Northeast Arctic has been more successful than the joint approach in the North Sea for the sustainable management of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and herring (*Clupea harengus*). By considering the short term economic costs and the current status of the North Sea fish stocks, we then ask if the Norwegian discard policy should be transferred to the North Sea stocks in order to make management of this area more effective and harmonious. Based on the results of this study we conclude that combined with a system of real time area closures and gear modifications, a ban on the discarding of cod, haddock, saithe and herring in the North Sea would provide substantial benefits to the stocks with minimal short term costs to the fishing industry. The major obstacle preventing the implementation of a discard ban would be the difficulties faced in enforcing it. However, new monitoring technology such as on board CCTV may dramatically improve compliance.

Contents

1. INTRODUCTION

Global per capita consumption of fishery products has increased by more than 80% in the last 40 years. Combined with an ever increasing human population the demand for fish continues to grow at a significant rate (FAO, 2007). However, 77% of ocean fisheries are either fully or overexploited and there is little room for expansion (FAO, 2007). Despite this insatiable demand for fish it is estimated that 8% of the fish caught each year are subsequently discarded (Kelleher, 2005). This equates to some 7.3 million tonnes of fish (Kelleher, 2005). Discards refer to any animal material that is caught during commercial fishing operations that is then subsequently returned to the sea (Kelleher, 2005). They include organisms which are alive as well as those that are dead (Kelleher, 2005). Despite covering just 0.2% of the world's oceans, between 1992 and 2001 the North Sea fisheries were estimated to be responsible for the discarding of over 13% of the estimated total global discards (Kelleher, 2005).

The North Sea is in the Northeast Atlantic region. It is bordered by seven different countries (Belgium, Denmark, France, Germany, the Netherlands, Norway and the UK), all of which have significant fishing interests in the North Sea. Effective management of this area thus becomes extremely difficult. The introduction of the European Union (EU) Common Fisheries Policy (CFP) in 1983 simplified the situation slightly since it meant that the six countries belonging to the EU were all managed under one policy. However, Norway maintains national control over its fisheries and its policies are somewhat different to that of the CFP. A major discrepancy in the two policies lies in their approach to discards. For vessels operating under Norwegian authority or in the Norwegian EEZ it is illegal to dump fish into the sea (Government of Norway, 2008), whether the vessel holds a licence for the catch or not, whereas for vessels operating under EU authority it is illegal to keep on board any species for which the vessel does not hold a licence (EU, 2009). Surprisingly, there do not appear to have been any previous quantitative studies examining the effectiveness and impact of the Norwegian ban on discards.

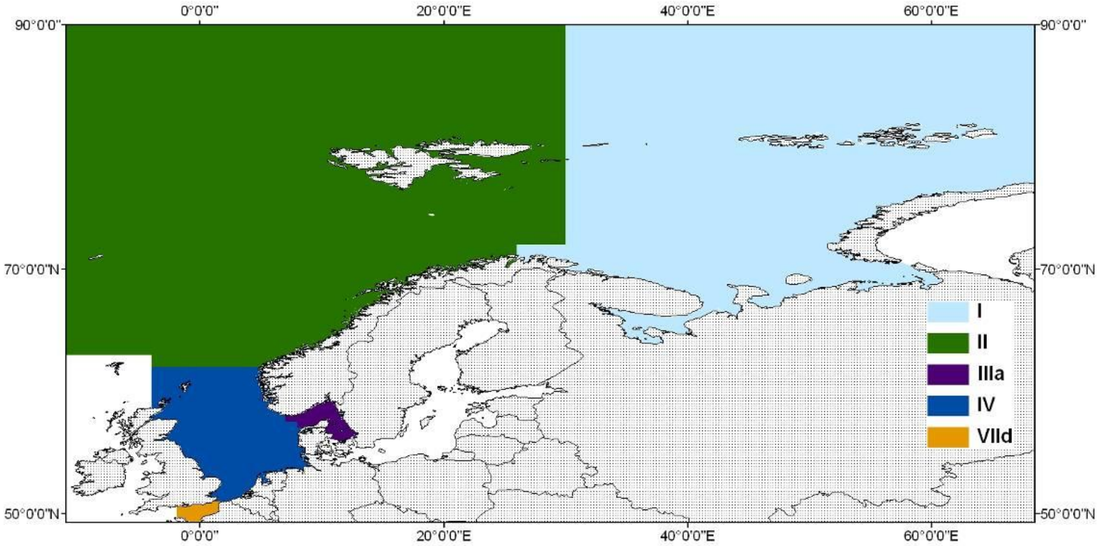

Figure 1.1 Map showing the geographic location of the ICES sub-areas. (ICES, 2009)

In this study we firstly introduce the problem of discards in the North Sea (ICES sub-area IV) and then assess the impacts of the Norwegian discard policy in the Norwegian Sea and around Spitzbergen (ICES sub-area II) and in the Barents Sea (ICES sub-area I). The geographic locations of the different ICES sub-areas are shown in figure 1.1. ICES sub-areas I and II will be referred to as the Northeast Arctic throughout our study. We then ask if the Norwegian approach to discards should be transferred to the North Sea EU fisheries in order to make management of the North Sea more effective and harmonious.

Initially the Norwegian discard ban only applied to commercial species (Wåge, 2007) and it is the effects of discarding commercial species of fish which will be addressed in this study. In particular we focus on cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and herring (*Clupea harengus*). These species are considered for four main reasons. Firstly, they are found in both the Northeast Arctic and the North Sea but form two distinct stocks. This allows the effects of different management approaches to be compared. Secondly, these species were the first to receive bans on discarding within the Norwegian EEZ (cod and haddock in 1987; saithe and herring in 1988 (Wåge, 2007)) and as such relatively substantial time series on the status of these stocks are available. The third point relates to the distribution of the Northeast Arctic stocks. Northeast Arctic saithe is found almost exclusively within the Norwegian EEZ (figure 1.2c). Northeast Arctic herring (Norwegian spring spawning herring) was so overfished in the 1970s and 1980s that at the time Norway implemented the discard ban it was also found almost exclusively within the Norwegian EEZ (Churchill and Ulfstein, 1992). Northeast Arctic cod and haddock migrate between the Norwegian EEZ and the Russian Federation EEZ (figure 1.2a and 1.2b). However, cod and haddock have been managed under a bi-lateral agreement since 1976 and Russia also has a discard ban on these species within its EEZ (Hallenstvedt, 1995; Honneland, 2000). Therefore, it is illegal to discard the Northeast Arctic species for almost the entirety of their range and they are likely to prove a good indicator as to the ecological effects of the Norwegian discard policy. Finally, in 1987 cod, haddock, saithe and herring made up 62% of the Norwegian catch by value[1]. Therefore these species will also provide a good indicator as to the economic effects of the Norwegian discard policy.

[1] Calculated using data obtained from Statistics Norway (2008).

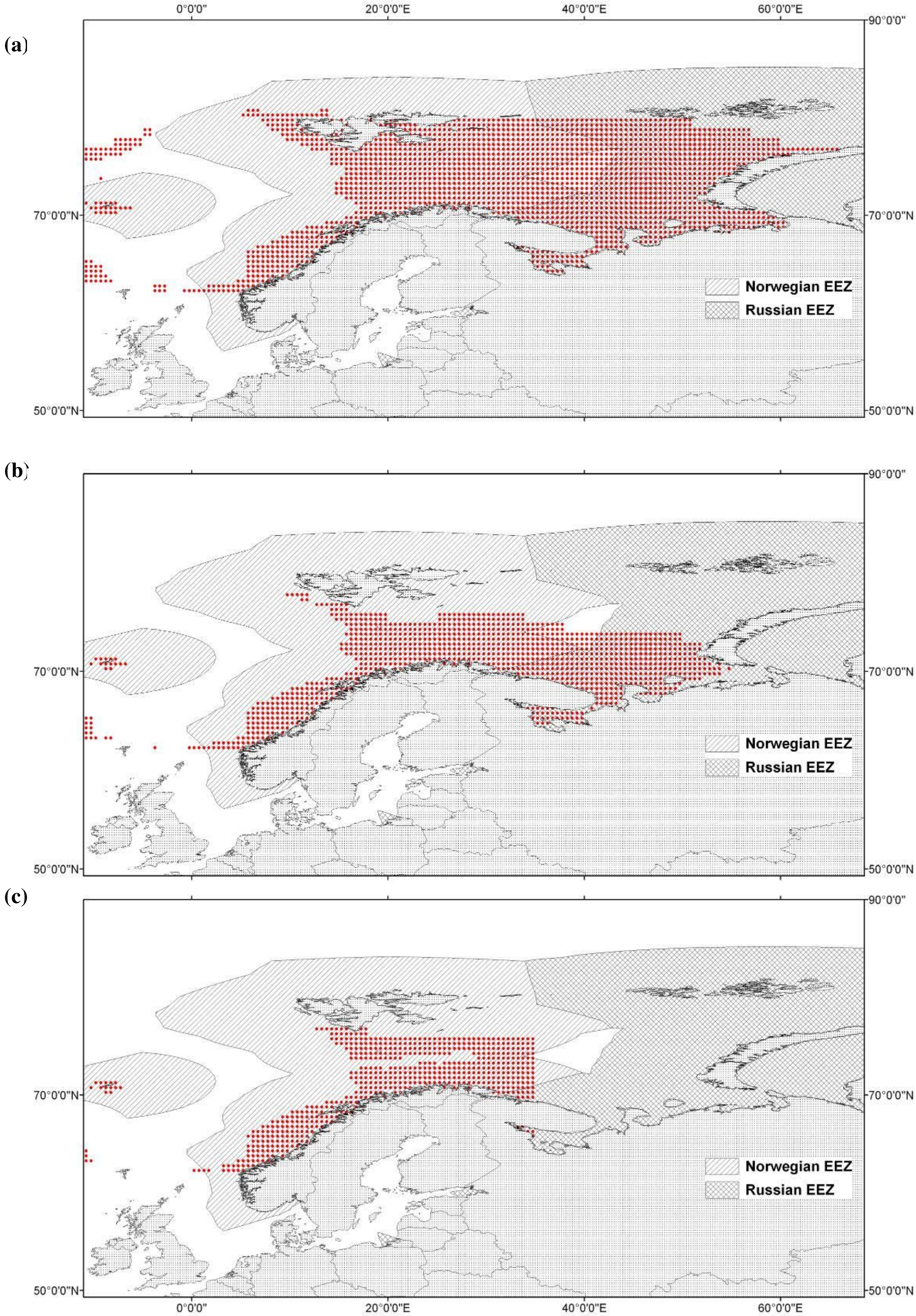

Figure 1.2 Map showing the geographic distributions of the Northeast Arctic stocks of (a) cod, (b) haddock and (c) saithe. Distribution data taken from AquaMaps (2009). EEZs taken from Flanders Marine Institute (2008).

1.1 The North Sea Fisheries

1.1.1 Discarding in the North Sea

The North Sea roundfish otter trawl fishery (targeting cod and haddock) is responsible for 24% of North Sea discards (Enever et al., 2009). In this fishery discards mainly consist of small-sized specimens of the target species (ICES, 2008a). It is estimated that 20 – 48% of the cod and 20 – 50 % of the haddock caught are discarded (Anon., 2002; Cotter et al., 2002). For haddock this equates to about 50,000 to 100,000 tonnes of discards each year (Kelleher, 2005). There are no discard estimates for the North Sea saithe fishery but the volume discarded in this fishery is considered to be small compared to the total catch (ICES, 2008a). However, there are reports of large hauls of saithe being discarded in other whitefish fisheries due to a lack of quota (Cappell, 2001). In general pelagic fisheries are considered to suffer from much smaller by-catch and discard rates than the bottom trawl fisheries since they are largely single species fisheries (Alverson et al., 1994). However, Pierce et al. (2002) found that about 11% of the herring caught in the Scottish 'maatje' herring fishery were subsequently discarded, mainly as a result of being too small.

1.1.2 A waste of resources

It is widely accepted that the dumping of fish at sea is unethical and represents a substantial waste of resources. There are a number of international statements and agreements, including United Nations (UN) resolutions that call for states and regional organisations to develop and implement techniques to reduce by-catch and discards (eg. FAO, 1995; UN, 1996).This culminated in UN resolution 57/142 of 2002 which urged action to reduce or eliminate by-catch and fish discards (UN, 2002). The direct loss of potential income through discarding in the North Sea has been estimated at 42% of the value of the total annual landings for the UK roundfish fishery (Cappell, 2001). In 1999 this equated to £11 million of cod and £31 million of haddock (Cappell, 2001). As well as direct losses discards also result in foregone potential future yield. In the otter trawl fishery discard mortality for cod and haddock is estimated at 100% (Lindeboom and de Groot, 1998; Cappell, 2001). As such these fish can neither be caught later nor do they contribute to stock recruitment. Discards are seen as a serious impediment to the rebuilding of stocks (ICES, 2008a).

Discarding not only results in a waste of physical resources but also results in the loss of valuable scientific information. The provision of scientific advice relies heavily on accurate fish stock assessments which in turn rely on accurate estimates of fishing mortality. Discard information is included in relatively few stock assessments due to the inaccuracy of the data (Kelleher, 2005). As a result estimates of fishing mortality can be substantially lowered leading to inaccurate conclusions and poor management decisions (Casey, 1996).

As well as being a waste of resources discarding also has wider ecosystem effects (Lindeboom and de Groot, 1998; Groenwold and Fonds, 2000; Votier et al., 2004). The direct impacts of continuing to discard, or reducing discards are not fully understood (Lindeboom and de Groot, 1998; ICES 2000). However, the European Commission (EC) considers that by-catches and discarding have a negative effect, both from ecosystem and economic perspectives and is committed to reducing unwanted by-catch and eliminating discards in European fisheries (Anon., 2007; 2009).

1.1.3 The reasons for discarding in the North Sea

The volume of fish that is thrown back into the sea is initially influenced by the composition of the catch, which is determined by social (gear regulations and fishermen's behaviour), environmental and biological factors (Maynou and Sarda, 2001; Bergmann et al., 2002). The decision to discard is then ultimately controlled by the fishermen who are further influenced by regulations as well as by economic forces (Gillis et al., 1995; Catchpole et al., 2005). Once the catch is onboard, reasons for discarding fall into three main categories; exclusion discarding, capacity discarding and high grading (Gillis et al., 1995). Exclusion discarding occurs because there is no market for the species or because there are regulations that prohibit the retention of the species. Capacity discarding occurs because there is either no physical room in the hold of the vessel or because the vessel has filled its quota, whereas high grading is the decision to discard marketable fish before the vessels capacity is filled. High grading is ultimately at the discretion of the fisherman and is based on whether the fisherman believes that he stands a good chance of catching a more profitable haul later on in the trip. On the other hand exclusion and capacity discarding occurs largely because of external pressures from markets or from management authorities. The CFP has come under public criticism because it requires member state vessels to discard all catches that they are not legally allowed to catch and so places external pressures on fisherman to exclusion and capacity discard (Booker, 2007). The EU's reasons for maintaining this policy are not so widely discussed.

In the late 1970s it was realised that fishing pressure was so high that simply using technical measures such as mesh size regulations was not enough to conserve fishery resources (Karagiannakos, 1996). New measures such as Total Allowable Catches (TACs), by-catch regulations and small fish restrictions which controlled the output of fisheries were put in place (Gezelius, 2008). Under EU law each of its 27 member states is individually responsible for penalising violators of EU regulations through 'criminal proceedings in conformity with their national law' (EU, 2002. Article 25). In many European states confiscation of goods or fines can only be issued as the consequence of a punishable act (Gezelius, 2008). This means in order to impose a penalty or confiscate fish the EU state has to prove the fisherman has acted without 'due care'. Due to the isolated nature of a vessel at sea and the fishermen's lack of complete control over his catch composition this can be extremely difficult to prove, greatly reducing the risk of penalty and thus reducing deterrents to pursue illegal catch or fish carelessly. The EU simplifies the legal problems of enforcing catch regulations by regulating acts that the fishermen can control. The EU's quotas are set for the catch landed and not for the fish caught (EU, 2002). This simplifies the question of 'due care', clarifies the criteria for criminal liability and makes enforcement much simpler to implement. The downside to this approach is that it not only allows fishermen to discard any catch that they feel is not economically worth keeping but it also forces them to discard potentially valuable fish if they are not licensed to catch them. EU discard policy thus focuses on indirect technical measures that try to reduce the initial capture of fish that are likely to be discarded. There are currently no direct measures in place that address the issue of discarding in EU fisheries (MRAG, 2007).

1.2 The Norwegian Discard Policy

When TACs were first introduced, fisheries law in Norway was similar to many European laws in that fish could only be confiscated if it resulted from a punishable act (Gezelius, 2008). As a result Norwegian fishermen were also expected to discard illegal catch to get around the problem of incidental catch and the random nature of fisheries (Government of Norway, 1955). Shortly after the introduction of TAC's discussions began on how to manage the unintentional exceeding of quotas. The Norwegian sales organisations were given the power to confiscate all catch that exceeded the vessels quota without having to prove the fisherman's liability (Government of Norway, 1983). This was thought to be an acceptable action on the grounds that fishermen do not own the catch they are not legally permitted to take (Gezelius and Raakjaer, 2008). It was not seen as a penalty and no fines were implemented for the landing of illegal catch. Further, although fishermen did not receive any financial gain from the 'illegal' catch it was not deducted from the vessels quota (Gezelius, 2006). This reduced the incentive for fisherman to pursue illegal catches without forcing the fisherman to discard their catch. This change in approach allowed Norway to introduce a ban on discards. In 1987 Norway introduced a ban on the discarding of cod and haddock (Wåge, 2007). This was followed by a ban on the discards of 6 other species including saithe and herring in 1988 (Wåge, 2007). The European Commission mentions the possibility of changing to this strategy in several recent communications (Anon., 2007 & 2009). In this study we assess the impacts of the Norwegian policy on the Northeast Arctic fisheries in order that the lessons learnt may be applied to the North Sea stocks.

In order to assess the impact of the Norwegian discard policy on the Northeast Arctic stocks a three pronged approach was taken. Firstly, evidence that the fishermen were complying with the ban was looked for. Secondly, the impacts on the fish stocks were assessed and finally impacts on the fishing industry were considered. The first prong tests the hypothesis that due to the remoteness of a vessel at sea, the low chance of being observed discarding and thus the difficulty in proving that a vessel has been involved in illegal discarding, the discard ban would have been extremely difficult to enforce and compliance would have been low. The second prong tests the hypothesis that a discard ban may not reduce fishing mortality. The unwanted fish will still be caught whether they are thrown back into the sea or they are landed. Further, allowing fishermen to land everything may reduce the incentive for them to fish selectively. It may generate new markets for undersized fish and as a result a discard ban may actually increase pressure on the fish stocks. The third prong aims to test the hypothesis that since some discarding occurs for economic reasons a discard ban will reduce the profitability of the fishing fleet. The fishing fleet will be constrained to land catches of lower value and it's competitiveness in what is an international fish market will be reduced.

1.3 A Comparison of Fish Stocks

The technological level of the fishing gear used by the European fleets is similar to the Norwegian fleets (MRAG, 2007). By-catch and discards in the North Sea roundfish fishery (cod, haddock and saithe) mainly consist of small or undersized roundfish (ICES, 2008a) and the North Sea herring fishery is largely a single species fishery (Pierce et al., 2002). The Northeast Arctic roundfish fishery is also mixed with the cod fishery taking by-catch of haddock and saithe (Ingólfsson et al., 2007; ICES 2008b) and the Northeast herring fishery is also a single species fishery although small by-catches of saithe are sometimes recorded (Norwegian Ministry of Fisheries and Coastal Affairs, 2006). Thus it can be concluded that the North Sea and Northeast Arctic fisheries for these species are relatively similar. The final question that this study asks is whether the present day North Sea fish stocks are in a comparable state to the late 1980s Northeast Arctic stocks and therefore whether similar rates of recovery are likely to be observed if a discard ban is implemented in the North Sea.

2 METHODS

2.1 Compliance

Estimates of discard rates have not been considered until relatively recently and are not available over the period of time with which we are concerned. Instead a more indirect approach to assess whether fishermen have reduced discards since the introduction of a discard ban was required.

2.1.1 Value of fish landed

If the discard ban was enforced effectively and fishermen were complying with the discard ban then this should be apparent in a number of ways. If the fishermen are no longer high grading then we would expect that the fish being landed by the Norwegian fleet would consist of smaller or poorer quality fish shortly after the implementation of the discard ban. By considering the value of the fish landed we can test if this is the case. Smaller and poorer quality fish are worth less per tonne. Thus if the discard ban is being adhered to we would expect the value per tonne of fish landed to decrease.

The quantity and value of cod, haddock, saithe and other codfishes caught was taken from Statistics Norway (2008). Other codfishes consist of tusk, ling, pollack, hake and whiting. The value is the money the fisherman receives for the first hand sale of the fish. The value of a tonne of codfish in Norwegian kroner was calculated for the period 1981 to 1998. The consumer price index for fish products is given by Statistics Norway (2008). The values were converted into 1998 prices using the mean consumer price index for each year. The values were then plotted to look for temporal trends.

2.1.2 Age composition of catches of Northeast Arctic cod

It is difficult to assess how policies or measures may have influenced catch composition over time since the data are likely to be heavily distorted by strong year classes or other environmental changes that may effect the composition of the fish stocks. It would be useful if the catch composition of two fleets, operating under different policies but who were fishing the same fish stocks could be compared.

Under the Norwegian Sea-water Fisheries act it is illegal for Norwegian vessels to discard fish (Government of Norway, 1983). Russia has a similar discard ban and it is also illegal for Russian vessels to discard (Hallenstvedt, 1995; Honneland, 2000). Since the Northeast Arctic cod stocks are shared between the Norwegian and Russian EEZs it is important that fishermen from both countries comply with the discard ban. If Russia continues to discard whilst Norway complies or vice versa then the effects of the policy on the stocks may be masked. For this reason the Norwegian and Russian catches are aggregated in this section and compliance is assessed in the Northeast Arctic as a whole.

Norway and Russia may trade some of their TAC with other countries in order to obtain quotas for other fisheries. EU vessels are allocated some of the Northeast Arctic TAC and so also fish within the Norwegian and Russian EEZs. However, it is only illegal for EU vessels to discard fish within the EEZs of Norway or Russia (Government of Norway, 1983). As a result it can be assumed that EU vessels which leave the bounds of these

EEZs in order to land their fish will continue to act as though no discard ban was put into place. In fact, upon re-entering EU waters it becomes illegal not to discard any fish for which the vessel does not have a licence to catch (EU, 2009).

If the Norwegian and Russian fleets are adhering to the discard ban then we would expect the EU fleets to be discarding at a higher rate since at least some of the EU vessels can be assumed to continue to discard. High grading involves throwing back the smaller, less valuable fish to make room for the larger more valuable ones. If the Norwegian and Russian fleets are complying with the discard ban and discarding to a lesser extent than the EU fleets then this should be apparent in the age composition of the catch. This provides us with a testable hypothesis for compliance within the Norwegian and Russian fleets. After the implementation of the discard ban the Norwegian and Russian fleets should be landing a larger proportion of the younger, smaller fish and a smaller proportion of the older, larger fish than the EU fleets. By comparing the age composition of the Norwegian and Russian fleets to the EU fleets at specific points in time the problems of temporal fluctuations in stock composition can be avoided.

The need to keep the stock compositions the same for the different fleets highlights a second reason why it is important to combine the Norwegian and Russian landings in this section. The EU fleets catch fish in both the Norwegian and Russian EEZs. The Russian EEZ is mainly an area for young cod whilst the majority of cod found within the Norwegian EEZ are mature adults (Garrod, 1977). By combining the Russian and Norwegian data the landings come from the whole of the Northeast Arctic and the stock compositions can be assumed to be the same as experienced by the EU fleet.

The Arctic Fisheries Working Group (AFWG) provides commercial catch data on the number of Northeast Arctic cod that were landed from 1946 (ICES, 2007). These data are available by age and nationality up until 1998 for ICES sub-areas I and II. The data were split into two groups - catches landed by the Norwegian and Russian fleets and those landed by the Spanish, German and Polish fleets (EU fleets). Landed catches for each group were then totalled for six three year periods spanning from 1981 to 1998. The mean ages and age distributions of the cod landed in each period were then calculated and plotted. The distribution of ages in the Norwegian and Russian catches were compared to that of the EU fleets for each three year period. Q-Q plots and Shapiro-Wilk tests were used to test for normality and Levene’s test looked for homogeneity of variance (Field, 2005). Since the data were non-normally distributed and had un-equal variances a Kolmorgorov-Smirnov Z test was used to test if the distributions were significantly different from one another (Field, 2005). The distributions were then plotted to show where the differences in distribution occurred.

2.2 Temporal trends in the status of stocks

Temporal trends in the health of the fish stocks were considered prior to and post the implementation of the different management policies in order to try to assess the impacts of the different strategies. Time series data on the spawning stock biomass (SSB) and the biomass at which the probability of recruitment failure is deemed high (B_{lim}) for the North Sea and Northeast Arctic stocks of cod, haddock, saithe and herring were taken from ICES (2008a; 2008b). Table 2.1 shows the time span of each series included in the analysis.

Table 2.1 The stocks included in the analysis and the time spans for which data were available.

Species	ICES Stock area	Time series span	
		Start	End
Cod	I and II	1946	2008
Cod	IV, VIId and IIIa	1963	2007
Haddock	I and II	1951	2008
Haddock	IV and IIIa	1963	2008
Saithe	I and II	1961	2008
Saithe	IV, IIIa and VI	1967	2007
Herring	I and II	1950	2008
Herring	IV, VIId and IIIa	1960	2006

Optimum levels of SSB vary between species and stocks such that directly comparing SSBs of different species would not be valid. The SSB was therefore divided by its associated B_{lim} value in order to obtain a normalised value that would allow for the status of different stocks to be compared (Garcia and Staples, 2000; Sparholt et al., 2007). Combining the status of the stocks enables general trends to be more easily seen than if they are considered on a stock-by-stock basis (Myers, 2001). For this reason the normalised SSB values for the four Northeast Arctic stocks were plotted on the same chart. The same was done for the North Sea stocks. To keep the analysis as transparent as possible means over the stocks by year and simple linear regression were used to explore the temporal trends. This was done for both the North Sea stocks and the Northeast Arctic stocks. For the Northeast Arctic stocks the regression was run once for the data points prior to and once for the data points post the discard ban in order to assess whether the ban had any effect on the status of the stocks. Similarly, for the North Sea stocks the regression was run once for data points prior to and once for data post the implementation of the CFP in 1983 in order to assess what effect this had had on the status of the fish stocks. Significance levels and confidence intervals were not calculated because the data are strongly autocorrelated. However, a leave-one-stock-out sensitivity analysis was carried out (Mosteller and Tukey, 1977).

2.3 Effects on the fishing industry

The value of the fish landed was already explored in section 2.1.1. However, the lower value of the fish landed may be offset by greater CPUE since fish are no longer been thrown back into the sea.

Time series data on the CPUE in ICES sub-areas I, IIa and IIb were taken from ICES (2008c). Data are available for Norwegian, Spanish and Russian trawls for Northeast Arctic cod and for the Norwegian trawls for Northeast Arctic saithe from 1983 up until 1995. The units used differ for some fleets so the CPUEs are not directly comparable. Instead temporal trends in CPUE for the fleets are considered.

2.4 A comparison of historic northeast Arctic stocks with the present North Sea stocks

In order to test if late 1980s Northeast Arctic fish stocks were in a similar state to the present North Sea stocks three major components need to be considered; SSB, the fishing mortality rate (F) and the proportion of juveniles. SSB is the number of mature individuals in the stock and F gives an indication of the fishing pressure on the stock. SSB and F give an indication of the stocks ability to replenish and are considered in Section 2.4.1. The proportion of juveniles is important since discards in the fisheries with which this study is concerned consist primarily of juveniles or undersized fish (ICES, 2008a). Thus a larger proportion of juveniles in the stock will result in larger proportions of by-catch. Section 2.4.2 compares the proportion of juveniles in the Northeast Arctic and the North Sea stocks.

2.4.1 Precautionary plot

A precautionary plot allows SSB and F to be compared at the same time. Data for the Northeast Arctic stocks of cod and haddock (1987) and saithe and herring (1988) were taken from ICES (2008b). Data for the North Sea stocks (2006) of the same species were taken from ICES (2008a). Data on the SSB, F, the biomass at which the stock is regarded as potentially depleted (B_{pa}) and the F at which there is a high probability of it being sustainable (F_{pa}) were used for this analysis. The SSB and F were normalised by dividing them by their reference values (Garcia and Staples, 2000 and Sparholt et al., 2007). B_{pa} and F_{pa} were used as the reference values because ICES does not provide F_{lim} information for either of the herring stocks (ICES, 2008a; ICES, 2008b). The normalised SSB of the Northeast Arctic stocks for the year that the Norwegian discard ban was introduced (1987 for cod and haddock, 1988 for saithe and herring) were plotted against normalised F values to form precautionary plots similar to those used by ICES (e.g. ICES, 2008a, p.154). The normalised SSB of the North Sea stocks for the year 2006 (the most recent year for which data are available) and their corresponding normalised F values were added to the plots for comparison. The mean normalised SSB and F values were calculated for the North Sea stocks and for the Northeast Arctic stocks. A Shapiro-Wilk's test was used to check for normality and Levene's test was used to test for homogeneity of variance (Field, 2005). Since there was no evidence of non-normality or heterogeneity one-way ANOVA was used to test for differences between the means of the two stocks (Field, 2005).

2.4.2 Stock maturity

Data were taken from ICES (2008a and 2008b). The percentage of juvenile fish in the stocks was calculated for Northeast Arctic cod and haddock (1987), Northeast Arctic saithe and herring (1988) and North Sea cod, haddock, saithe and herring (2006). The percentage of juvenile fish in the stocks was calculated using the equation:

$$\text{Juvenile fish (\%)} = \frac{TSB - SSB}{TSB} * 100$$

Where, TSB = total stock biomass.

The proportions of juvenile fish in each fish stock were arcsin $\sqrt{x}$ transformed (Underwood, 1991). A Shapiro-Wilk's test and Levene's test found no evidence of non-normality or heterogeneity (Field, 2005). One-way ANOVA was used to test if there was a difference between the proportions of juvenile fish in the pre-discard ban Northeast Arctic stocks and the 2006 North Sea fish stocks (Field, 2005).

3 RESULTS

3.1 Compliance

3.1.1 Value of fish landed

The normalised first sale value of one tonne of codfish landed by the Norwegian fleet is shown in figure 3.1. The value of codfish follows a similar trend for all species. Around 1986-1987 the value per tonne of codfish landed begins to decrease for all species. The value per tonne of codfish landed then begins to increase again around 1988-1989 for all species.

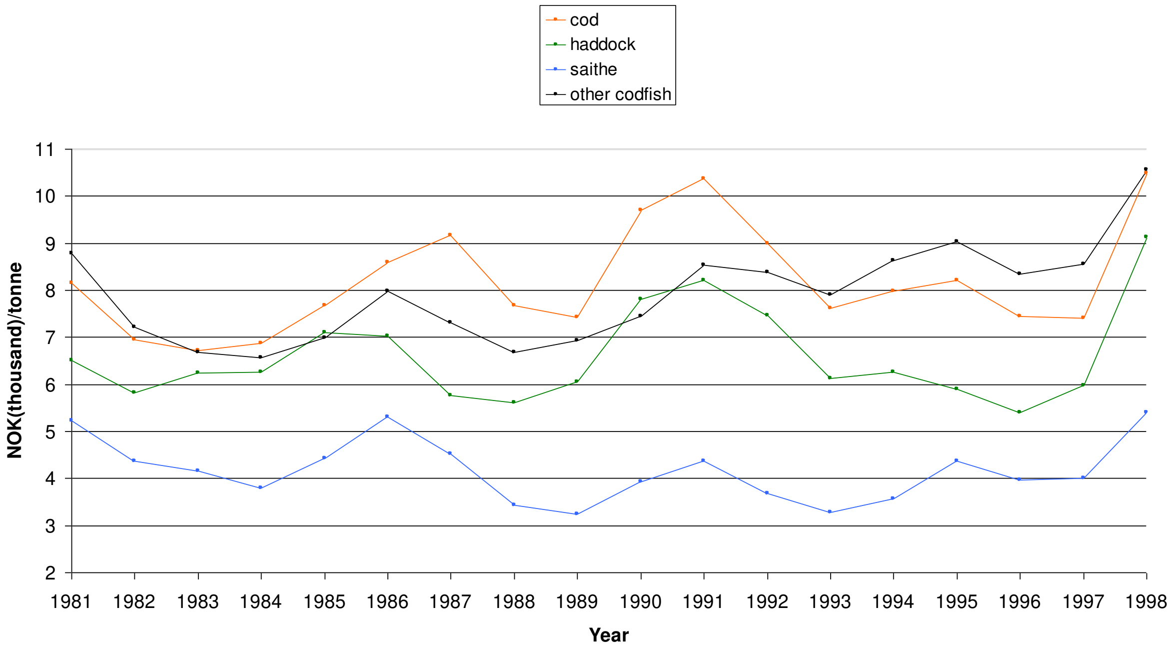

Figure 3.1 The value of one tonne of Norwegian codfish by year (1998 prices).

3.1.3 Age composition of catches of Northeast Arctic cod

Figure 3.2 shows the mean age of Northeast Arctic cod that was landed between 1981 and 1988 for the Norwegian and Russian fleets and for the EU fleet. Figure 3.3 shows the age distributions of the cod landed by the different fleets for this period with the corresponding Kolmorgorov-Smirnov Z statistic. Prior to the introduction of the discard ban the average age for the Northeast Arctic cod landed by the Norwegian and Russian fleets was older than for the fish landed by the EU fleet (figure 3.2). The distributions of the ages for the cod landed by the different fleets were significantly different (p<0.001) with the Norwegian and Russian landings consisting of smaller proportions of young fish and larger proportions of older fish (figure 3.3a and 3.3b). After the introduction of the discard ban on cod in 1987 Norway and Russia started landing fish that were, on average, younger than the EU fleet (figure 3.2). Norway and Russia's cod landings now consisted of proportionally more young fish and proportionally less older fish than the EU fleet (p<0.001) (figure 3.3c, 3.3d, 3.3e and 3.3f).

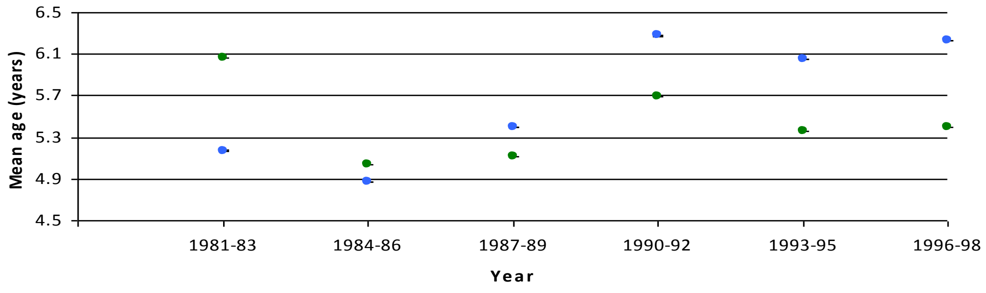

Figure 3.2 Mean age of Northeast Arctic cod that was landed by the Norwegian and Russian fleets (Green) and the EU fleet (Blue)between 1981 and 1988. The standard error bars are shown.

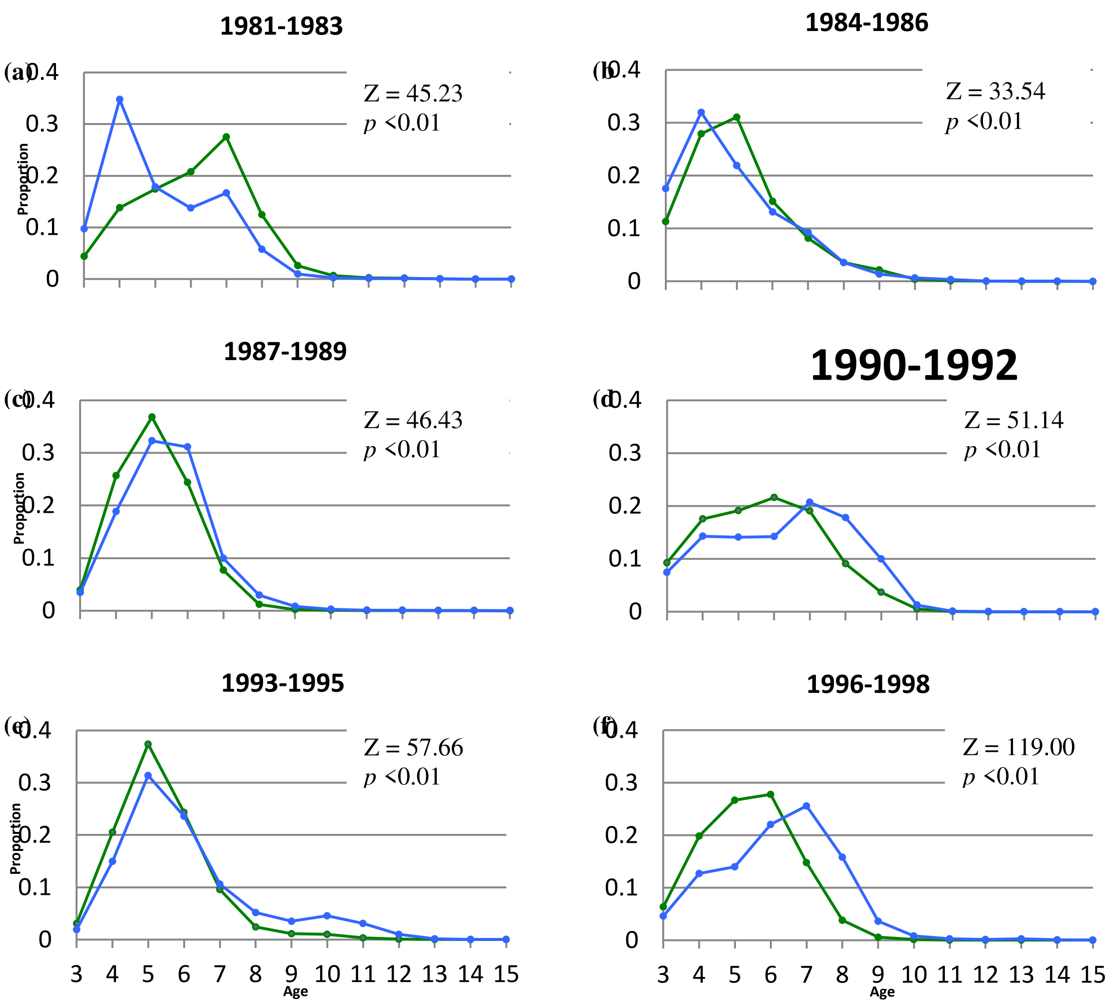

Figure 3.3 Distribution of ages for the Northeast Arctic cod landed by the Norwegian and Russian fleets (Green) and the EU fleet (Blue) between 1981 and 1998. The Kolmorgorov-Smirnov Z statistic and corresponding p values are shown in each panel.

3.2 Temporal trends in the status of stocks

The temporal trends in the normalised SSB for the Northeast Arctic and North Sea stocks of cod, haddock, saithe and herring are shown in figure 3.4. The normalised SSB of the Northeast Arctic stocks (figure 3.4a) declined at a rate of 7% per year up until the discard ban was implemented. Post discard ban the normalised SSB of the Northeast Arctic stocks increased at a rate of 18% per year. The normalised SSB of the North Sea stocks (figure 3.4b) declined at a rate of 6% per year until 1983 when the common fisheries policy (CFP) was implemented. After this date the normalised SSB of the North Sea stocks began to increase at a rate of 3% per year. The rates of change from the leave-one-stock-out sensitivity analysis are shown in table 3.1. For the Northeast Arctic stocks the largest range in the rate of change occurred for the post-discard ban data. Increase in normalised SSB ranged from 12% (if saithe are excluded) to 23% (if cod are excluded) per year, compared to 18% if all stocks are included. For the North Sea stocks the largest range in the rate of change occurred for the post CFP data. Increase in normalised SSB ranged from 2% (if haddock are excluded) to 6% (if cod are excluded) per year, compared to 3% if all stocks are included. Therefore, the results are relatively robust to this sensitivity analysis and it can be concluded that the observed temporal trends are not been driven by just one species in the analysis.

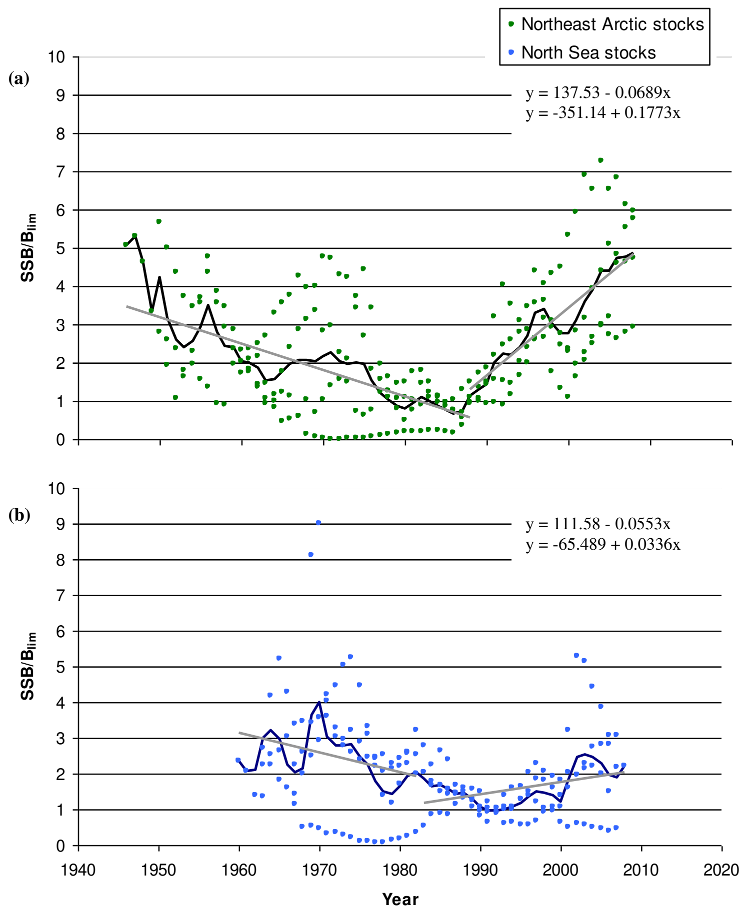

Figure 3.4 Normalised SSB for (a) the Northeast Arctic and for (b) the North Sea stocks of cod, haddock, saithe and herring by year. The black line represents the mean values by year and the grey lines are the linear regressions (parameters are given in each panel).

Table 3.1 The rate of change of the standardized SSB for the Northeast Arctic and North Sea stocks when certain stocks are excluded from the regression analysis.

	Rate of change (% per year)			
	Northeast Arctic		North Sea	
Species	Pre-discard ban	Post-discard ban	Pre-CFP	Post-CFP
- None	- 6.9	17.7	- 5.5	3.4
- Cod	- 7.8	23.0	- 6.3	6.4
- Herring	- 4.9	18.6	- 6.9	3.0
- Haddock	- 8.0	18.0	- 3.3	1.5
- Saithe	- 7.3	11.5	- 7.1	2.4

3.3 Effects on the fishing industry

The temporal trends in CPUE for various fleet's catch of Northeast Arctic cod are shown in figure 3.5. The Norwegian total CPUE for cod began to decrease in 1987 and had declined by 75% before reaching a low in 1991 (figure 3.5a). The fastest rate of decline occurred between 1987 and 1988 during which time the CPUE was reduced by 42%. By 1993 the total Norwegian CPUE was back above the 1987 total CPUE. CPUE in ICES sub-areas IIa and IIb showed much greater rates of change than ICES sub-area I. The Spanish trawls targeting cod in ICES sub-area IIb displayed a very different trend in CPUE (figure 3.5b). The Spanish CPUE continued to rise after 1987 increasing by 173% by 1991. By 1994 the Spanish CPUE was back at similar levels to those experienced in 1987. No temporal trends were apparent in the Russian CPUE for cod (figure 3.5b). Russian CPUE ranged from a low of 0.23t/hr (1992 ICES sub-area IIb) to 1.14t/hr (1986 ICES sub-area IIa and 1994 ICES sub-area IIb).

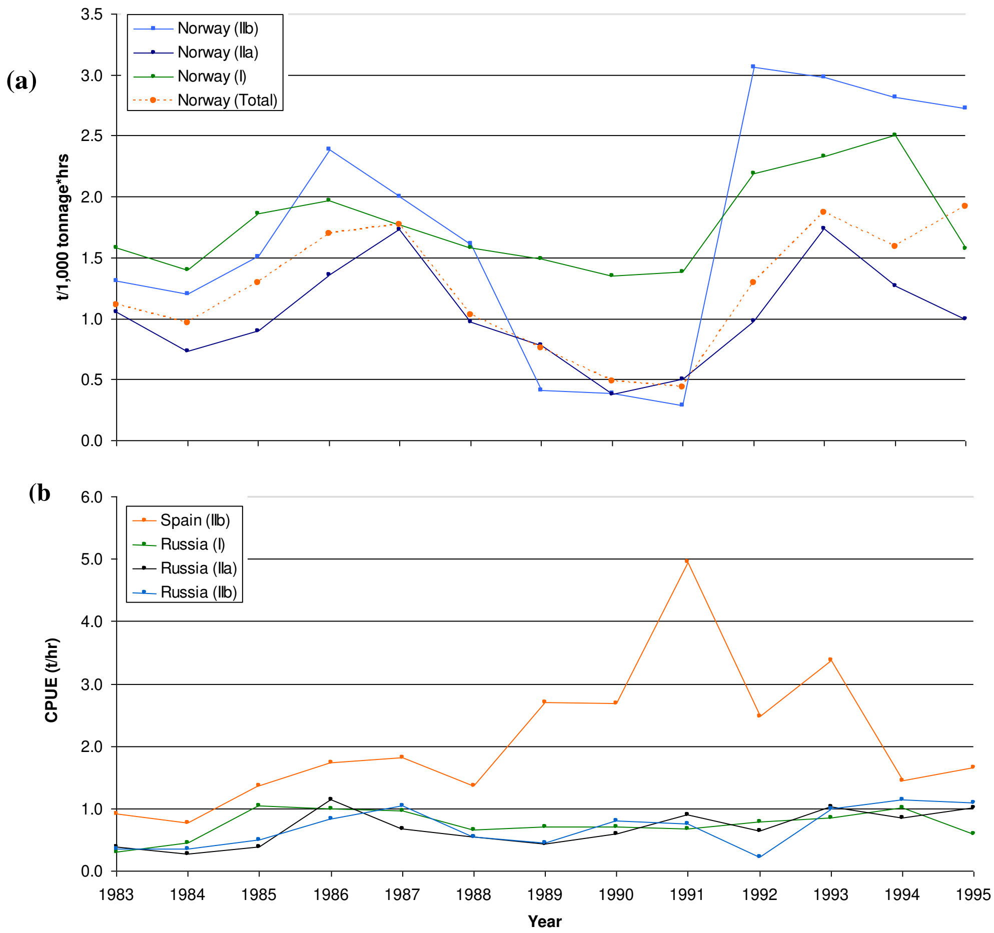

Figure 3.5 Northeast Arctic cod catch per unit effort for (a) the Norwegian trawls and for (b) the Spanish and Russian trawls in ICES sub-areas I, IIa and IIb.

The temporal trends in the Norwegian CPUE for Northeast Arctic saithe are shown in figure 3.6. Between 1988 and 1990 CPUE decreased by 16%. However, by 1992 CPUE was above late 1980 levels peaking in 1993 at 1t/hr.

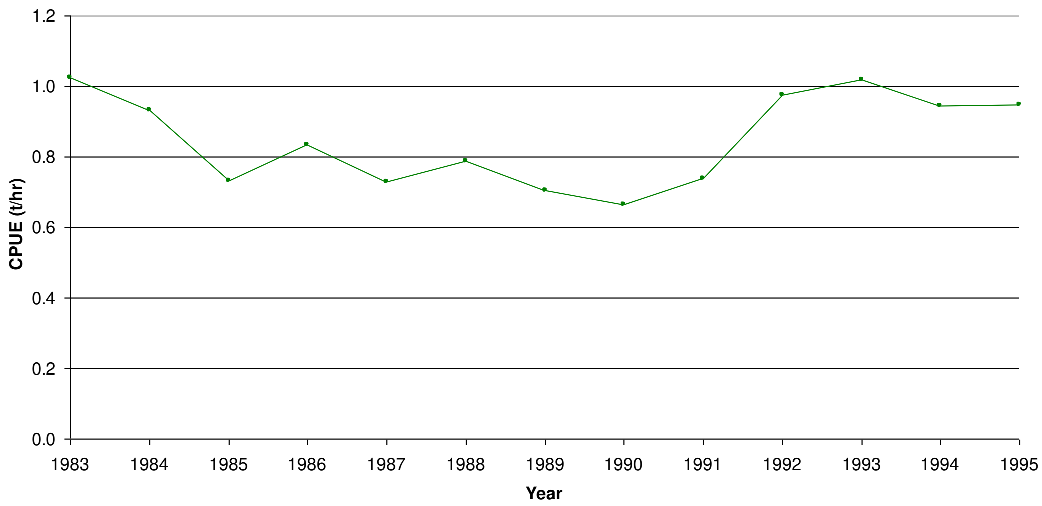

Figure 3.6 Northeast Arctic saithe catch per unit effort for the Norwegian trawls.

3.4 A comparison of historic northeast Arctic stocks with the present North Sea stocks

3.4.1 Precautionary plot

The status of present North Sea stocks and Northeast Arctic stocks at the time that the Norwegian discard ban was introduced are shown in figure 3.7. Present North Sea stocks of haddock and saithe are in much better condition than any of the Northeast Arctic stocks were in when the Norwegian discard ban was implemented. Generally the North Sea stocks have higher levels of normalised SSB than the Northeast Arctic stocks and experience lower levels of fishing mortality. Only present North Sea stocks of cod contain lower levels of normalised SSB than the Northeast Arctic stocks. The mean normalised SSB for the North Sea stocks (1.2) was higher than that of the historic Northeast Arctic stocks (0.6). However, this was not statistically significant (t_6=-1.465, *p*=0.19). The mean fishing mortality rate for the North Sea stocks (1.0) was also lower than the Northeast Arctic stocks (1.6) though again this was not statistically significant (t_6=1.3, *p*=0.18).

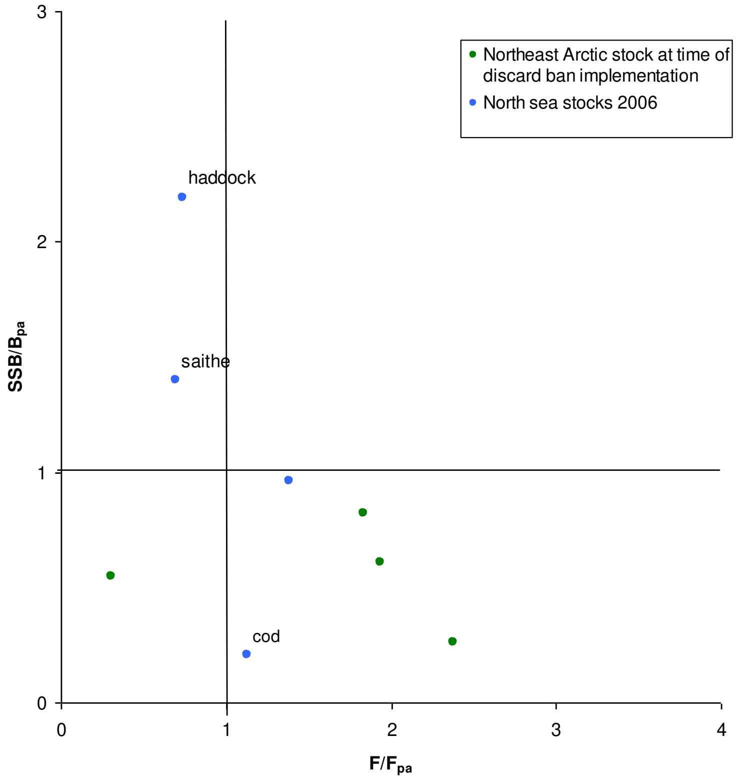

Figure 3.7 Normalised spawning stock biomass against the normalized fishing mortality for Northeast Arctic cod and haddock in 1987, Northeast Arctic saithe and herring in 1988 and North Sea cod, haddock, saithe and herring in 2006.

3.4.2 Stock maturity

The percentage of juvenile fish in each stock is shown in figure 3.8. The mean arc sine $\sqrt{x}$ transformed proportion of juvenile fish was very similar in the present North Sea stocks (0.91) to the historic Northeast Arctic stocks (0.94). There was no statistical evidence to suggest that these proportions were different from one another (t_6=0.13, *p*=0.90). However, the mean proportion of juvenile fish in the Northeast Arctic stocks is strongly influenced by the low proportion of juvenile fish in the Northeast Arctic herring stocks. The historic Northeast Arctic stocks of cod, haddock and saithe all contained a larger percentage of juveniles than their equivalent present day North Sea stocks (figure 3.8).

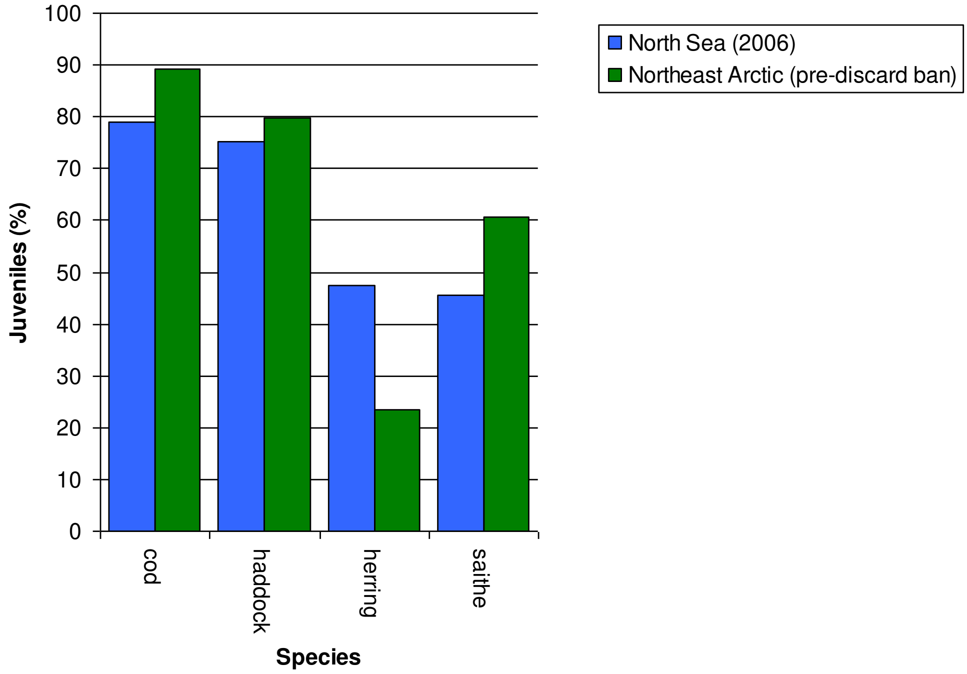

Figure 3.8 The percentage of juveniles in the present North Sea and pre-discard ban Northeast Arctic stocks of cod, haddock, herring and saithe.

4 Discussion

After the introduction of the discard ban the Norwegian and Russian fleets started landing larger proportions of small fish and smaller proportions of large fish than the EU fleet. This was followed by substantial stock recovery rates in the Northeast Arctic. The Norwegian fleet initially began landing fish of lower value and Norwegian CPUE effort declined, although the period of decline lasted just 4 years. Most present day North Sea stocks have higher SSBs and lower F than the pre-discard ban Northeast Arctic stocks with similar proportions of juveniles present in both areas.

4.1 Compliance

The average value of the cod landed in Norway decreased after the introduction of a ban on cod discards in 1987 (figure 3.1). This was also true for the landings of haddock and saithe after the implementation of their respective bans (figure 3.1). These results provide evidence that smaller and/or lower quality fish were being landed after the introduction of the discard ban and appear to show that the discard ban was being at least partially adhered to with less of the low value fish being discarded.

However, the value of the haddock and saithe actually began to decrease before the discard bans were put in place. Further, similar patterns were also found for other codfishes which were not subject to a ban on discards (figure 3.1). It is therefore likely a significant quantity of the low quality fish being landed can be explained by fluctuations in the status of the fish stocks at that time and not by the implementation of a discard ban. Thus, on a temporal scale it is difficult to separate the effects of poor stock status from the effects of a policy change on the size and quality of the fish being landed.

Within the EEZs of Norway and Russia minimum mesh size and gear regulations are set for the operating area and not by the vessels flag state (UN, 1982). Comparing the catch composition of two different groups of fleets fishing the same stocks, under the same technical regulations, one of which is assumed to be continuing to discard to at least some extent, enables us to check for a reduction in discarding behaviour in the other fleet. Prior to the discard ban the Norwegian and Russian fleets were landing significantly smaller proportions of young and significantly larger proportions of old cod than the EU fleets (figure 3.3a and 3.3b). This suggests that prior to the discard ban the Norwegian and Russian fleet's discarding rates were actually greater than those of the EU fleet. After the ban on the discarding of cod was put into place in 1987 the Norwegian and Russian fleet began landing greater proportions of younger, smaller cod and smaller proportions of the older, larger cod (figure 3.3c, 3.3d, 3.3e and 3.3f). This supports the idea that the Norwegian and Russian fishermen were at least partly adhering to the ban on discards and high grading to a lesser extent than the EU fleet. Exclusion discarding and capacity discarding occur mainly for legislative reasons which are removed if a ban on discards is introduced, whereas high grading occurs mainly in order that fishermen can maximise the profitability of their catch. This makes high grading much more difficult to enforce. For this reason, a reduction in high grading in the Norwegian and Russian fleets indicates that other forms of discarding are also likely to have been reduced.

The Norwegian government enforced the discard ban largely by monitoring the landings with regards to the quantity and size distribution (Gezelius, 2006). This was relatively easy to set up in Norway since all firsthand sales of fish go through just six sales organisations (Gezelius, 2006). On board inspectors from the Directorate of Fisheries and inspections by the Coast Guard were also carried out (MRAG, 2007). Due to the vast area covered by the Norwegian EEZ these inspections were largely just to provide catch composition information for the sales organisations. It is extremely difficult to monitor activities at sea and as a result the number of reported infringements that have later been prosecuted is small (Gezelius, 2006; MRAG, 2007). The discard ban appears to be adhered to largely on a voluntary basis. This is supported by the fact that violations of Norwegian fisheries policy are no more frequent in the Protection Zone around Svalbard than in the Norwegian EEZ despite the fact that violations within this Zone cannot be punished due to Svalbard's unsettled jurisdictional status (Hønneland, 2000). Part of the voluntary compliance may be explained by the fact that representatives of the fishermen are directly involved in the regulatory decision process with the explicit aim of enhancing the legitimacy of regulations (Hønneland, 2000).

Current discard estimates for Norway are relatively low and are between 2-8% (Valdermasson and Nakken, 2002) but a ban on discards has not completely eliminated the problem of discarding in the Norwegian and Barents Seas. In order to increase compliance, soft enforcement schemes whereby fishermen would be paid 20% of the value of any unlicensed fish which they landed were experimented with in the late 1990s but with mixed success (Gezelius, 2008). These schemes reduce incentives to discard and ease enforcement but increase the incentives to target 'illegal' fish.

There would be a number of problems for enforcement of a discard ban in the North Sea area. Fish caught and landed in the North Sea are landed and sold in at least six EU countries all with different legal systems as opposed to just six sales organisations in Norway. This makes monitoring of the catch composition and prosecution of offenders much more difficult. One encouraging option is the development of a voluntary CCTV scheme, currently being trialled to monitor discarding in Scottish fisheries (WWF 2009). Other electronic monitoring devices may also be useful (McElderry et al., 2007). As well as the problems with hard enforcement, voluntary compliance is also unlikely to be as high as experienced in the Northeast Arctic. Unlike the Norwegian system which is largely supported by fishermen (Hønneland, 2000), dissatisfaction with the current CFP is widespread amongst EU fishers (Ritchie, 2003). However, although there was little support from fishermen for a discard ban in the North Sea in the past (Cappell, 2001), the position of the industry appears to be changing – with support emerging for a gradual move towards a discard ban (NSRAC 2009).

4.2 Temporal trends in the status of fish stocks

One of the main objections against the implementation of a discard ban is that allowing fishermen to land everything removes the incentive for fishermen to try to fish selectively or for them to adhere to their allocated quotas. Fishermen may deliberately target smaller fish if they are much more abundant than their larger counterparts and the pressure on the fish stocks may actually increase. However, since the implementation of the discard ban in Norway the SSB of cod, haddock, saithe and herring has improved at a rate of 18% per year (figure 3.4a). In comparison the North Sea has experienced a much slower rate of recovery (figure 3.4b). The increase in stock health will have been influenced by a variety of natural and anthropogenic factors and cannot be attributed solely to the Norwegian management policy or the discard ban. However, a ban on discards greatly improves estimates of fishing mortality. This will have helped make effective management decisions and is likely to have contributed strongly to the recovery of the fish stocks. At the very least, the implementation of the discard ban does not seem to have hindered the recovery of these stocks and suggests that fisherman have remained selective in their targeting of these species.

In order to ensure that fishermen remain selective Norway has combined the discard ban with two other main instruments. After the introduction of the discard ban 'unlicensed' fish were confiscated and the fishermen received no compensation (Gezelius, 2006). The value of the fish accrued directly to the sales organisation and so fishermen had no incentive to target them. The fishermen still faced costs associated with the hold space and processing of the fish and so this acted as a disincentive to target them. Further, a system of real time closed areas was established (Graham et al., 2007). If the catch to undersize and by-catch ratio is above a certain limit then the surrounding area is immediately closed. The vessel must then steam five miles before it is allowed to resume fishing (Graham et al., 2007). In combination with technical measures (e.g. fitting grids in trawls - see below) this system is also credited with having had a large influence on the recovery of North-east Arctic fish stocks (WWF 2008).

There are a number of similarities between the North Sea and Northeast Arctic areas. The North Sea fisheries for cod, haddock and saithe consist mainly of discards of small sized roundfish (ICES, 2008a). Similarly, the Northeast Arctic roundfish fishery is mixed with hauls targeting cod containing by catches of haddock and saithe (Ingólfsson et al., 2007; ICES 2008b). Like the Norwegian herring fishery, the North Sea herring fishery is a single species fishery with the by-catch nearly completely consisting of herring which are too small (Pierce et al., 2002). The two fishing fleets are also comparable with the European fishing fleet and the Norwegian vessels using similar technology (MRAG, 2007). The potential also exists for a faster rate of stock recovery in the North Sea. Most North Sea stocks currently have larger normalised SSBs and experience lower rates of fishing mortality at present than the pre-discard ban Northeast Arctic stocks (figure 3.8). Further, cod in the North Sea have been shown to grow faster than those living at higher latitudes and North Sea haddock reach maturity at age 2-3 years compared to 4-5 years elsewhere (FAO, 2009). The use of real-time closures to reduce discards of cod has also been experimented with in the Scottish fishery in the North Sea since 2007 (Scottish Government 2007), and has received widespread support from the fishing industry, scientists and conservation groups (WWF 2009).

4.3 Effects on the fishing industry

In the late 1980's the SSB of the Northeast Arctic stocks were below the precautionary limits set by ICES (figure 3.7) and they contained high proportions of juveniles (figure 3.8). The discard ban and the associated closed area regulations will have thus initially resulted in a large number of closed areas within Norway's EEZ. Fishermen will have had to fish much more selectively in order to ensure they could continue fishing in that area. Further, if they couldn't they would have to spend time steaming at least 5 miles to a new fishing ground. Both of these actions will have reduced Norwegian CPUE and this is shown by the steep decline in Norwegian CPUE for Northeast Arctic cod after the discard ban was introduced (figure 3.5a). Similarly CPUE for saithe decreased after the introduction of a ban on discards in 1988 (figure 3.6). A decrease in CPUE may also be a result of decreasing quantities of fish in the stock. However, CPUE for Spanish cod trawlers within ICES sub-area IIb continued to increase (figure 3.5b) over this period suggesting that decreasing quantities of fish in the stock was probably not the reason for this decline. A reduction in CPUE combined with lower values of fish being landed caused operating costs to exceed operating revenues (figure 4.1) and for a short period the industry was reliant on government subsidies. Government subsidies to the fishing industry peaked at 1.1billion kroner in 1990 (Milazzo, 1998). This equates to about £100 million at today's exchange rate. An interesting side point here is that the Norwegian CPUE for cod did not decrease as significantly in ICES sub-area I as it did in sub-area II. Since compliance with the ban seems to have been largely voluntary there is no reason to suggest that compliance should be lower in sub-area I than in II. It is more likely that this is as a result of the different minimum catch sizes (MCS) in the two areas. In the Norwegian EEZ (sub-area II) the MCS for cod is 47cm whereas in the Russian EEZ (sub-area I) the MCS for cod is 42cm (Cappell, 2001). Thus the smaller MCS in the Russian EEZ appears to have reduced the costs to the fishing vessels operating in sub-area I.

The lack of profitability created strong incentives for fishermen to find ways in which they could enter the closed areas. In the early 1990's investigations began into the use of grid technology to improve the selectivity of cod trawls (Isaksen et al., 1992 cited in Graham et al., 2007).These were demonstrated to improve compliance with catch composition regulations and gave fishermen access to areas which would previously have been closed. The decline in CPUE lasted for just 4 years, the fishing fleet was profitable again by 1991 and by 1993 the CPUE was back above pre-discard ban levels. By the mid 1990's more than 100 Norwegian vessels were using the grid technology on a voluntary basis (Lobach and Veim, 1996). The use of these sorting grids are now mandatory for cod and shrimp trawls in Norway's EEZ north of 62°N (WWF 2008).

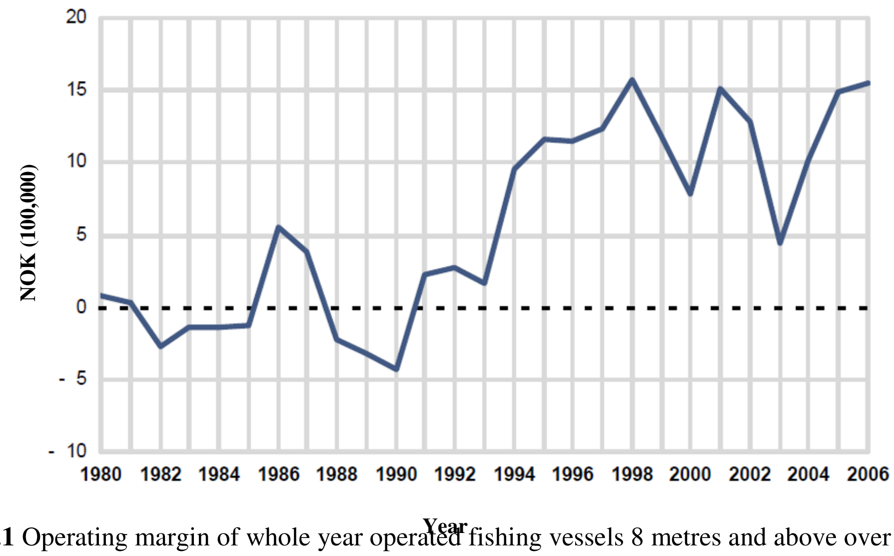

Figure 4.1 Operating margin of whole year operated fishing vessels 8 metres and above over the period 1980-2006. Converted to 2006 value by means of consumer price index. Taken from Statistics Norway (2008).

As highlighted in section 4.2 most current North Sea stocks are already in better condition and also have the potential to recover much more quickly than the Northeast Arctic stocks. At 35cm the minimum landing size (MLS) is also much smaller than the Norwegian and Russian MCS's (47cm and 42cm respectively) (Cappell, 2001). Therefore, the initial cost to the industry is likely to be much smaller and economic recovery much quicker than that experienced by Norway. The economic reliance on the fishing industry is also much smaller in the EU than it was in Norway. In 1987 1.5%[2] of Norwegians employed were employed in the fishing industry. This compares to current rates of 0.14%[3], 0.13%[4], 0.01%[5] and 0.04%[6] for Denmark, France, Germany and the UK respectively. Further, North Sea fisheries are made up of a wide variety of alternative species (Sustainable Development of European Coastal Zones 2009), whereas cod, haddock, saithe and herring dominate Norwegian fisheries, accounting for 62% of the total by value[7]. Therefore, should it be deemed that additional governmental support would be required during the early stages of a discard ban, this amount would likely be proportionally smaller than the amount required from the Norwegian government.

A problem highlighted by the EC in its communication on the subject (Anon., 2002) is what to do with all the excess, undersized and low value fish that is landed. At present the EU does not have the same capacity as Norway to produce industrial products such as fishmeal from low value fish. Transporting low value fish large distances in order to be processed is likely to be unprofitable and require large subsidies. However, a booming aquaculture industry across Europe is demanding evermore fishmeal (Tidwell and Alan, 2001). Producers are unable to keep up with demand and prices of fishmeal have rocketed, increasing by 274% between May 1999 and April 2009 (Index Mundi, 2009). Under these conditions it is likely that the current low capacity to produce fishmeal would be rapidly replaced by profitable processing industry generating additional jobs and money within the fisheries sector.

5 Conclusion

We have shown that since its implementation in 1987 the discard ban has received at least partial compliance within the EEZs of Norway and Russia. Discarding still occurs but at a significantly lower level than in the North Sea (Kelleher, 2005). Allowing fishermen to land everything does not appear to have increased pressure on the fish stocks. On the contrary, combined with a system of real time area closures the discard ban appears to have generated an incentive for fishermen to install gear modifications and fish more selectively. This, combined with greater scientific knowledge about the status of the stocks is likely to have contributed to the relatively fast stock recovery rates experienced in the Northeast Arctic. Initially, the economic cost to the fishing industry was relatively high with fishermen experiencing lower catch values and lower CPUE. However, the period for which the fishing sector remained unprofitable lasted for just four years. Today, the Norwegian and Barents Sea fisheries are some of the most prosperous in the world with the TAC for Northeast Arctic cod amounting to between 7-800,000 tonnes a year since the early 1990s (Honneland, 2000).

In comparison the TAC for North Sea cod has declined from a peak of 250,000 tonnes in 1985 (ICES, 1992) to just 29,000 tonnes today (EU, 2009) and the North Sea stocks as a

[2] Calculated using data obtained from Statistics Norway (2008).

[3] Calculated using data obtained from Eurostat (2007) and Danmarks Statistiks (2009).
[4] Calculated using data obtained from Eurostat (2007) and Statistiches Bundesamt Deutschland (2009).
[5] Calculated using data obtained from Eurostat (2007) and the Institut National de la Statistiques et des Études Économiques (2009).
[6] Calculated using data obtained from the Marine and Fisheries Agency (2008) and the UK Office for National Statistics (2009).
[7] Calculated using data obtained from Statistics Norway (2008).

whole have performed poorly since the introduction of the CFP in 1983. The North Sea fisheries for cod, haddock, saithe and herring are relatively similar to those in the Northeast Arctic and the potential exists for rates of stock recovery exceeding those experienced by Norway since the late 1980s. The economic reliance on these fisheries in the North Sea is also smaller and the short-term negative impacts on the industry of a discard ban are likely to be significantly less than experienced by Norway in the late 1990s. The potential also exists to expand the fish processing industry to make use of those fish which are not suitable for human consumption.

The main obstacle to a discard ban on these species in the North Sea would be that of enforcement. Hard methods of enforcement are extremely difficult and expensive to carry out, especially in six different legal systems. Soft strategies that create incentives to land 'illegal' catches can also generate incentives to target them. However, new developments to monitor fishing activity, such as on-board CCTV, is showing great promise.

Norway's positive experience with the discard ban provides evidence that a ban on the discarding of cod, haddock, saithe and herring would produce positive results if transferred to the North Sea. Gaining support from the fishing industry and voluntary compliance from the fisherman will now be crucial if a discard ban is to be successfully implemented.

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